4. A SYNOPSIS OF LABORATORY ACTIVITIES AND THEIR CONTEXT

NASA Enterprises and Priorities

This section provides a brief overview of Laboratory research activities, and places these investigations in the context of priorities generated by NASA Headquarters.

The Laboratory has a long history of theoretical and experimental research on the atmosphere of the Earth and of other planets. Laboratory activities, therefore, address two of the four NASA Enterprises shown in Table II.

Table II: The Four NASA Enterprises

Earth Science Looks toward our planet to better understand the interactions of its system components and develop a capability to predict its future evolution.
Space Science Explores our star system and beyond to better understand the universe and the origin of life.
Human Exploration and Development of Space (HEDS) Expands the human presence beyond the Earth.
Aeronautics and Space Transportation Technology (ASTT) Develops and transfers innovative flight technologies.

The bulk of the research in the Laboratory is congruent with the five scientific areas of research identified as Earth Science priorities. Earth Science is NASA's contribution to the U.S. Global Change Program. Earth Science is an ambitious program designed to investigate the Earth as an integrated system. It presents great scientific challenges and has important practical implications. The research priorities for the Earth Science Enterprise are shown in Table III.

Table III: NASA's Earth Science Enterprise Science Priorities

Atmospheric Ozone To detect and identify causes of atmospheric ozone changes and evaluate consequences.
Seasonal-to-Interannual Climate Prediction To provide global observations and gain scientific understanding to improve forecasts of the timing and geographic extent of transient climate anomalies.
Long-Term Climate Variability To provide global observations and gain scientific understanding of the mechanisms and factors which determine long-term climate variations and trends.
Land Cover Change and Global Productivity To report and understand the trends and patterns of change in regional land-cover, biodiversity, and global primary production.
Natural Hazards To apply Earth Science remote sensing science and technologies to disaster characterization and risk reduction from earthquakes, wildfires, volcanoes, floods, and droughts.

The space science activities in the Laboratory relate to both of the fundamental questions of the Space Science Enterprise. The two questions are shown in Table IV.

Table IV: NASA's Space Science Enterprise Fundamental Questions

How did the universe, galaxies, stars and planets form and evolve? How can our exploration of the universe and our solar system revolutionize our understanding of physics, chemistry and biology?
Does life in any form, however simple or complex, carbon-based or other, exist elsewhere than on planet Earth? Are there Earth-like planets beyond our solar system?

The way the Laboratory's activities integrate with priorities generated at NASA HQ is depicted in Figure 2.

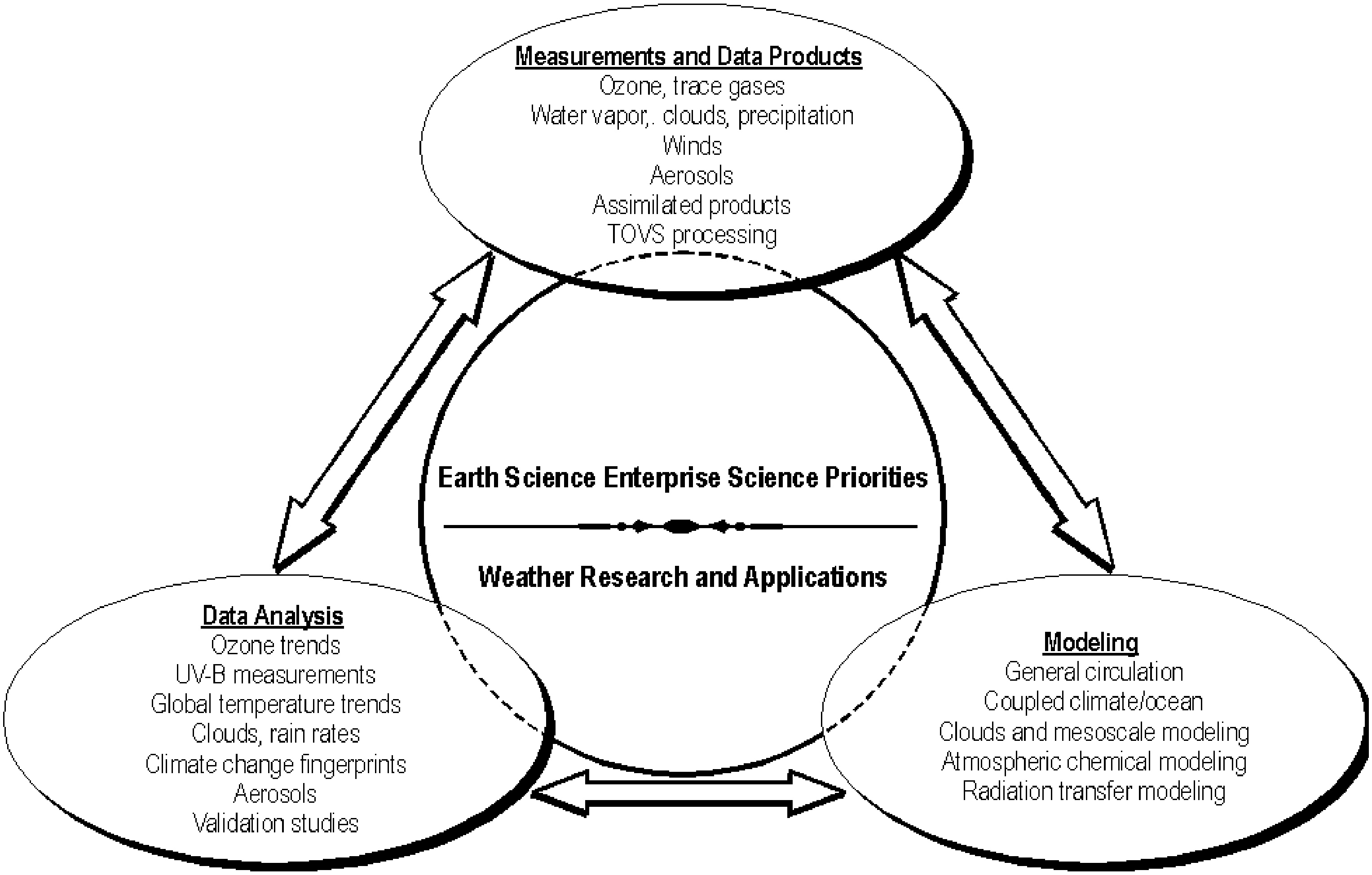

Figure 2

Details of major Laboratory activities and highlights from calendar year 1997 are discussed in Sections 5 and 6, respectively.

Atmospheric Sciences

The basic and applied research in Earth system science performed by the scientists in the Laboratory for Atmospheres covers a broad range of temporal and spatial scales, and is relevant to both the short-term weather forecasting and longer-term climate studies. This breadth of Laboratory activities is due to the historical evolution of atmospheric research at Goddard, from the early days of weather satellites and emphasis on weather forecasting to the present focus on global change and climate.

Several activities in the Laboratory are in support of the operational satellite program of the National Oceanic and Atmospheric Administration (NOAA). Project scientists for the Polar-Orbiting Operational Environmental Satellite (POES) and the Geostationary Operational Environmental Satellite (GOES) are from the Laboratory. Studies and development of new instruments are sponsored by the Integrated Program Office (IPO).

For ease of description, the activities of the Laboratory can be divided into three groups: measurements, data products and data analysis, and modeling. These divisions are somewhat artificial, in that activities in one area often affect those in another; these groups are strongly interlinked and cut across science priorities and the organizational structure of the Laboratory. The grouping corresponds to the natural processes of carrying out scientific research: ask the scientific question, identify the geophysical variable needed to answer it, conceive the best instrument to measure it; analyze the data; and ask the next question. These groups are strongly interlinked and cut across science priorities as well as the organizational structure of the Laboratory.

Measurements

The experimental activities in the Laboratory are distributed throughout the Branches. Instruments range from *in situ* sensors that are flown on balloons, aircraft, and planetary probes to sample the atmosphere locally, to remote-sensing sensors deployed on the ground, aircraft, or satellites to observe the atmosphere over a broader range of spatial and temporal scales. The remote-sensing instruments operate at a variety of wavelengths, ranging from ultraviolet to microwave, and include both passive sensors that measure atmospheric scattering and emission, and active sensors, such as lidars and radars.

The Laboratory scientists pioneered the development of the backscatter ultraviolet technique in the 1960s that led to the development of the widely known Total Ozone Mapping Spectrometer (TOMS) instrument. These concepts are being employed to develop the next generation of passive remote sensing instruments to make observations from space. The lidar techniques are evolving from primarily ground and aircraft-based instruments to Shuttle and free-flying satellites to measure clouds, aerosols, and atmospheric winds. Future applications include the measurement of chemical constituents by tuning the laser light to suitable frequencies.

Data Products and Data Analysis

A substantial resource of the Laboratory is devoted to the reduction of raw, instrumental data into useful geophysical parameters, and analysis of data collected by sensors all over the world, including data from field campaigns and satellite missions.

Laboratory activities in the area of data products involve developing improved algorithms to extract new information from satellite sensors flown previously, and assimilating data from multiple sensors to produce internally-consistent, spatially and temporally homogeneous data sets. These Data Assimilation Office (DAO) products are in heavy demand from scientists all over the world, as they allow scientists to interpolate reasonable values in regions where observational data are lacking.

Some of the research areas with which the Laboratory has involvement in data products and data analysis are as follows:

Climate Variability and Global Change

Advanced analysis techniques are used to identify natural variability on seasonal, interannual, and inter-decadal time scales, and to isolate it from changes due to anthropogenic causes. The data analysis will be carried out in conjunction with modeling studies for physical interpretation and hypothesis testing. The use of satellite and remote sensing data are of primary importance. Other ancillary data used include those from ground-based observations, ocean arrays, aircraft and measurement platforms in field campaigns.

Regional Climate Variability

Studies of regional climate variability provide a direct link between global climate information and societal needs, which is a major priority recommended by the Intergovernmental Panel on Climate Change (IPCC). In the Laboratory this effort is just beginning.

Observational and modeling studies of precipitation, river run-off, fresh water fluxes and related hydrologic processes have been carried out for various climatic regions of the world. These observational studies provide benchmarks and working hypotheses for simulations and validation studies using regional climate models.

Atmospheric Ozone Research

Ozone affects life on the Earth in deleterious and beneficial ways. Ozone in the troposphere contributes to smog formation, and can therefore have bad effects on the biosphere. However, ozone in the stratosphere acts as a protective shield, preventing harmful ultraviolet (UV) radiation from reaching lower altitudes, where such radiation could damage genetic material.

Data from many ground-based, aircraft and satellite missions are combined with meteorological data to understand the factors that influence the production and loss of atmospheric ozone.

Aerosols/Cloud Climate Interactions

Extensive studies are underway on the optical properties of aerosols and their effectiveness as cloud condensation nuclei. A variety of data from satellite and experimental campaigns are being analyzed to assess the direct and indirect effects of aerosols on climate.

Water Vapor and Clouds

Multisensor observations have been utilized to study moisture and water droplet distributions. Analysis of aircraft data shows the potential for contrail cirrus as an anthropogenic factor in climate change. Studies are underway to determine the overall effect of aircraft generated cirrus on climate.

Rain Measurements from Space

Laboratory scientists have been involved in developing algorithms to measure rain rates from space by analyzing satellite data and radar- and ground-based information. These analyses are essential to better understand the global hydrologic cycle.

Modeling Studies

To support the overall goals of Earth Science, scientists in the Laboratory develop a variety of computer models to understand historical changes in the atmosphere, and to predict its future state in response to both natural and human-induced perturbations. Models play an essential role in the interplay between observations and interpretations of atmospheric behavior.

Atmospheric models are being developed and used in the following areas:

Cloud Resolving Models

Two- and three-dimensional cloud and regional scale models are used to study classical meteorological problems such as convective systems in the tropics and in mid-latitudes, transport of aerosols and trace gases, stratospheric-tropospheric exchange, and air-sea-land (including vegetation) interactions and their cloud-climate feedback. Cloud models are an intrinsic part of the development of retrieval algorithms designed to make maximum use of data that will be produced by the TRMM mission. Regional models are also used to develop and test parameterization schemes to be utilized in General Circulation Models (GCMs) and to understand regional-scale hydrological cycle physical processes.

General Circulation Models

General Circulation Models (GCMs) are an essential tool to study seasonal, inter-annual, and inter-decadal time scales and to isolate natural variability from anthropogenic global change signals. In collaboration with the Laboratory for Hydrospheric Processes, substantial efforts are devoted to studying the El Nino Southern Oscillation (ENSO) with the ultimate goal of assessing the role of satellite data on our ability to study and predict the phenomenon. Particular attention is devoted to the development of parameterization codes for radiation and moisture processes which play an essential role in climate sensitivities to cloud microphysics, water vapor, and other trace gases, and in the global water and energy cycles.

Regional Climate Models

General circulation models can now provide reasonably reliable results on global and continental time scales for simulating sub-continental and sub-synoptic scale climate variabilities. Improved simulation and prediction of local features are needed for regional scale impact assessments of climate change. These inadequacies can be addressed with Regional Climate Models (RCMs).

RCMs generally consist of limited-domain mesoscale (10-50 km resolution) models nested within general circulation (100-500 km resolution) models and/or global, four-dimensional assimilated data. For more detailed processes, a cloud resolving (1-2 km resolution) model can be further nested in the mesoscale domain. Nested RCMs can be used to model detailed atmospheric processes and interactions with the Earth's surface using the large-scale conditions provided by general circulation models or four-dimensional data assimilation. Regional Climate Modeling is a nascent effort in the Laboratory.

Trace Gas Modeling

Trace gas models simulate the short- and long-term behavior of atmospheric ozone in response to natural and anthropogenic influences. Models differ in the manner they account for transport processes, the chemical reactions between the various atmospheric constituents, and the coupling between these processes.

Space Science Activities

Ion and neutral composition, neutral temperature and wind, and electron temperature and density measurements have been made by Laboratory instruments on the Atmosphere Explorers, Dynamics Explorer, Pioneer Venus Orbiter, and the Galileo missions.

Laboratory for Atmospheres scientists have just completed work on the gas chromatograph mass spectrometer (GCMS) to measure the chemical composition of gases and aerosols in the atmosphere of Titan, and on the ion and neutral mass spectrometer (INMS) to measure the chemical composition of positive and negative ions and neutral species in the inner magnetosphere of Saturn and in the vicinity of the icy satellites. Both instruments are flying on the Cassini mission. Work is nearing completion on a neutral mass spectrometer (NMS) to measure the neutral atmosphere of Mars, to be flown on a joint mission with Japan.

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The responsible NASA official is Bob Theis.